

AMENDMENTS TO THE SPECIFICATION

In the Specification

Please substitute the following amended paragraph(s) and/or section(s) (deleted matter is shown by strikethrough and added matter is shown by underlining):

Page 2, line 12-line 27,

The calculation of the movement vectors of the nodes of the meshwork can be carried out according to various methods. First of all there are putting into correspondence or “matching” methods consisting of testing a discrete set of possible values of movement vectors for each node of the meshwork and of retaining the best vectors according to a given criterion. A second method known as a transformed method consists of using the properties of the Fourier transform and its extensions so as to convert the movement into a phase jump in the transformed space. Finally, there is a third method known as a differential method for determining the movement vectors by ~~optimising~~ optimizing a mathematical criterion (for example a quadratic error between the image and its aforesaid value with the movement field). This method is most frequently used for estimating movement with ~~modélisation~~ modelization by finished elements. A conventional differential method for ~~optimising~~ optimizing movement vectors is the Gauss-Newton method. The present application concerns more particularly the movement estimation method family using a model of finished elements and a differential method to determine the movement field.

Page 3, line 15 – page 4, line 17,

One object of the invention concerns a method for estimating movement in which the meshwork is ~~optimised~~ optimized during estimation so as to obtain at the end of the method of meshwork adapted to the semantic contents of the images. To this effect, the finished elements are refined during the movement estimate.

Another object of the invention is to improve the effectiveness of the Gauss Newton method so as to ~~optimise~~ optimize the movement vectors of the nodes of the meshwork. To this effect, this ~~optimisation~~ optimization is carried out on several resolution levels of the images.

Finally, another aim of the invention is to provide a method for estimating movement so as to avoid aforesaid pathological situations. To this effect, the invention provides adding during the movement vectors ~~optimisation~~ optimization step constraints so as to avoid these situations.

Also, the invention concerns a method for estimating the movement between two numericals image I_1 and I_2 with luminance Y_1 and Y_2 and intended to generate for each point of coordinates x, y of the image I_2 a movement vector $\vec{d}(x, y) = (d_x, d_y)$ so as to form an image \hat{I}_2 from the image I_1 with luminance $\hat{Y}_2(x, y) = Y_1(x - d_x, y - d_y)$ which is an approximation of the image I_2 , ~~characterised~~ characterized in that it comprises the following steps:

- (a) defining an initial model of finished elements comprising a meshing whose nodes are points of the image I_2 , a movement vector at each node of said meshing, and an interpolation formula calculating the value of the movement vector of each point of the image I_2 from the values of the movement vectors of the nodes of the mesh to which it belongs,
- (b) ~~optimising~~ optimizing the value of the movement vectors of the model according to a differential method,
- (c) calculating a variation E between the image I_2 and the image \hat{I}_2 for each finished element or mesh,
- (d) carrying out a finer meshing on a discrete fraction of the set of finished elements determined according to a criterion relating to the variations E and allocating a movement vector to each new meshing node,
- (e) repeating the steps (b), (c) and (d) on the model of finished elements obtained at the end of the preceding step (d) until a stoppage criterion is satisfied.

Page 4, line 25 – line 30,

Finally, according to a preferred embodiment, constraints are added to the movement of the finished elements at the time of ~~optimising~~ optimizing the movement vectors so as to avoid the reversal of the finished elements. According to another embodiment, it is also possible to introduce constraints so as to avoid the flowing over of the meshing obtained after applying the movement vectors beyond the sphere of the image l_1 .

Page 6, line 16 – line 20,

According to the invention, as the movement is gradually estimated, the value of the movement vectors of the meshing nodes known as nodal vectors is ~~optimised~~ optimized and the meshing is locally densified when this is necessary. Advantageously, this ~~optimisation~~ optimization shall be carried out on several resolution levels starting with a low resolution level.

Page 7, line 13 – line 30,

According to step (b), the value of the movement vectors of the model are ~~optimised~~ optimized according to a differential method, such as the Gauss-Newton method or its Marquardt extension. This ~~optimisation~~ optimization can be free, that is without constraints imposed on the possible values of the nodal vectors, or with constraints. The nodal vectors denote the movement vectors of the nodes of the meshing. ~~Optimsation~~ Optimization with constraints is directly linked to free ~~optimisation~~ optimization and forms the subject of an embodiment given in detail later in the text.

The free ~~optimisation~~ optimization technique used here makes use of the advantageous characteristics of the Gauss-Newton method (rapid convergence of the optimum) and the

gradient method with adaptive step (global convergence towards a local optimum) to resolve the linear system to be followed. This technique is an iterative correction of the movement vectors $\vec{d}(x, y)$ making it possible to obtain from the start a rough approximation of the movement. The number of iterations k for this ~~optimisation~~ optimization of the movement vectors is either specified by the user at the start of the method, or depends on a threshold linked to the maximum variation between two consecutive values of nodal vectors for two successive iterations. Below are details of the Marquardt extension of the Gauss Newton ~~optimisation~~ optimization method.

Page 9, line 13 – line 15,

At the end of this ~~optimisation~~ optimization phase, there are available N nodal vectors each relating to one node of the meshing.

Page 11, line 25 – line 29,

In practice, the images l_j are obtained by the filtering of the image l_i using a linear low pass filter only allowing $1/2^r$ of the spectral band of the image in question in the directions x and y , that is a pulse response filter h_n^r having a pass-band $BP_r = [1/2^{r+1}, 1/2^{r+1})$ in the space of ~~standardised~~ standardized frequencies $[-1/2, 1/2]$. The image l_i^r is defined by the following equation:

Page 12, line 10 – line 13,

As indicated previously, this ~~optimisation~~ optimization on several resolution levels is able to improve and accelerate the convergence of the calculations of the movement vectors. It is to be noted that the number of resolution levels R selected may differ from the number of successive refinings carried out on the meshing.

Page 13, line 7 – line 9,

According to the invention, this constraint is associated with each triangle at the time the movement vectors are ~~optimised~~ optimized. The step of ~~optimising~~ optimizing the movement vectors amounts to a system of the type:

Page 13, line 15 – line 19,

So as to resolve the ~~optimisation~~ optimization problems under constraints, the so-called increased Lagrangian technique is used. This technique is described in the work entitled “Theories and algorithms” by Michel Minoux, Volume 1, pp ~~257-260~~ 256-259, published by Dunod 1983. This technique combines two ~~optimisation~~ optimization techniques: Lagrangian ~~optimisation~~ optimization and the ~~optimisation~~ optimization of external penalties.

Page 14, line 5 – line 6,

The constraints g_e have been previously ~~linearised~~ linearized by the Taylor formula to the order 1:

Page 14, line 9 – line 17,

The ~~optimisation~~ optimization method is then the following:

- $k = 0$ is ~~initialised~~ initialized
- $\lambda = 0$ and $r = 0$ are placed, $\lambda \in \mathbb{R}^m$ and $r \in \mathbb{R}^m$, and m denotes the number of triangles of the model
- then the minimum $\delta D_{k+1}(\lambda, r)$ is determined so that on iteration $k+1$,
- $$H.\delta D^{k+1} = \nabla E^k - C'\gamma$$

where $\gamma' = (\lambda, r)$, C' is a matrix of $\Re^{2N} \times \Re^{2m}$

$C'\gamma$ forms a matrix of the ~~linearised~~ linearized constraints having for coefficients the following values: